Routledge
Taylor & Francis Group

Journal of Environmental Policy & Planning

ISSN: 1523-908X (Print) 1522-7200 (Online) Journal homepage: http://www.tandfonline.com/loi/cjoe20

Trade-offs and synergies in joint knowledge creation for coastal management: insights from ecology-oriented sand nourishment in the Netherlands

Franke van der Molen, Jac. A. A. Swart & Henny J. van der Windt

To cite this article: Franke van der Molen, Jac. A. A. Swart & Henny J. van der Windt (2018): Trade-offs and synergies in joint knowledge creation for coastal management: insights from ecology-oriented sand nourishment in the Netherlands, Journal of Environmental Policy & Planning, DOI: 10.1080/1523908X.2018.1461082

To link to this article: https://doi.org/10.1080/1523908X.2018.1461082

Published online: 06 Apr 2018.

JOURNAL OF ENVIRONMENTAL POLICY & PLANNING, 2018
https://doi.org/10.1080/1523908X.2018.1461082

Trade-offs and synergies in joint knowledge creation for coastal management: insights from ecology-oriented sand nourishment in the Netherlands

Franke van der Molen*, Jac. A. A. Swart and Henny J. van der Windt

Science and Society Group, Faculty of Mathematics and Natural Sciences, University of Groningen, Groningen, The Netherlands

ABSTRACT

In order to successfully inform environmental management, environmental research needs to balance legitimacy, credibility, and salience. This paper aims to identify trade-offs and synergies between these three attributes in collaborative research for environmental management, and draws lessons for organizing such research. Empirically, it draws on a study of a research program on the ecological effects of coastal protection through sand nourishment. Our findings suggest that the legitimacy and salience of knowledge creation, particularly in an interactive governance context, are complementary. At the same time, we found trade-offs between practical relevance and fundamental knowledge creation, as well as between issue diversity and the depth and quality of scientific inquiry. Balancing the legitimacy, credibility, and salience of knowledge may be enabled by interactive knowledge creation involving policy-makers, experts and stakeholders. We conclude that successful management-oriented environmental research, particularly in the case of wicked problems, requires both a careful design of arrangements for stakeholder engagement, and well-established linkages to broader regulatory and institutional contexts.

ARTICLE HISTORY
Received 12 February 2016
Accepted 2 April 2018

KEYWORDS
Coastal management; participatory research; legitimacy; credibility; salience

1. Introduction

A key issue in various domains of environmental management is how to create and mobilize knowledge that can effectively inform collective action with respect to the environment. In an influential paper, Cash et al. (2003) have argued that knowledge creation efforts must be respectful of disparate concerns and values of involved actors, meet standards of scientific and technical quality, and be relevant for decision-making and management. This triad of legitimacy, credibility, and salience has been widely applied in studies of environmental knowledge-policy interactions (e.g. Runhaar, Van der Windt, & Van Tatenhove, 2016; Tuinstra, Hordijk, & Kroeze, 2006). Various authors have argued that trade-offs between the three attributes may occur, as efforts to strengthen one of them weaken the others (Cash et al., 2003; Sarkki et al., 2014; White et al., 2010). Other authors have argued that synergies between the attributes may emerge as well (Hegger, Lamers, Van Zeijl-Rozema, & Dieperink, 2012). However, little research has examined such trade-offs and synergies in detail.

This paper aims to create insights into trade-offs and synergies between the legitimacy, credibility, and salience of knowledge in collaborative environmental knowledge creation and into the processes that enable successful knowledge creation for environmental management. Here, success is a multifaceted notion. It may relate to balancing legitimacy, credibility, and salience, but also to various forms of impacts on policy or management.

CONTACT Franke van der Molen f.vandermolen@science.ru.nl; franke.vandermolen@gmail.com Science and Society Group, Faculty of Mathematics and Natural Sciences, University of Groningen, P.O. Box 221, 9700AE, Groningen, The Netherlands
*Current affiliation: Institute for Science in Society, Radboud University, P.O. Box 9010, 6500 GL, Nijmegen, The Netherlands.

Cash et al. (2003, p. 8086) argue that the effectiveness of scientific inputs for policy should not only be evaluated in terms of the ensuing policy actions, but also 'in terms of impacts on how issues are defined and framed, and on which options for dealing with issues are considered'.

This paper address two research questions: what trade-offs and synergies occur between legitimacy, credibility, and salience in collaborative research for environmental management? And what lessons can be learned for organizing environmental research that balances these three attributes? The empirical basis of this paper is an investigation of a collaborative research program on the ecological effects of sand nourishment (Ecology-oriented Sand Nourishment, ESN, 2009–2015). In the Netherlands, sand nourishment is used to counter coastal erosion and to facilitate coastal resilience. However, uncertainties and knowledge lacunae persist regarding the ecological effects. The ESN research program aimed to produce knowledge on these effects. In the light of our research questions, this program is an interesting case because it was a collaborative effort that aimed at producing scientifically valid knowledge that was both expected to address the diverging concerns of various societal organizations and to inform coastal management practices. Thus, it aimed at combining credibility, legitimacy, and salience.

The next section provides a review of the environmental management literature that focuses on legitimacy, credibility, and salience. Section 3 outlines the methods and data, and section 4 describes the broader coastal policy and management background. Section 5 presents the program's efforts to achieve legitimacy, credibility, and salience, and section 6 analyses the trade-offs between them. Finally, section 7 draws conclusions and discusses how trade-offs may be dealt with in organizing collaborative and management-oriented environmental research.

2. Legitimacy, credibility, and salience: literature review

We performed literature searches in Web of Science and Google Scholar using legitimacy, credibility, and salience as keywords. For the latter term, we also used 'relevance' as an alternative. We selected papers in Web of Science categories that may relate to environmental management, such as 'environmental sciences', 'biodiversity conservation', 'ecology', and 'public administration'.

The term legitimacy has different connotations in different social, political, and legal contexts. In the context of knowledge creation, legitimacy reflects 'the perception that the production of information and technology has been respectful of stakeholders' divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests' (Cash et al., 2003, p. 8086). This includes fairness and trustworthiness in dealing with disparate standards and perspectives (Bauler, 2012; Holden, 2013). Credibility 'involves the scientific adequacy of the technical evidence and arguments'; thus, it is a measure of scientific and technical quality (Cash et al., 2003, p. 8086). In the literature, various attributes have been connected to the notion of credibility, which include the accuracy, reliability, validity, and authoritativeness of knowledge (Cook, Mascia, Schwartz, Possingham, & Fuller, 2013; Koetz, Farrell, & Bridgewater, 2012; White et al., 2010). Salience 'deals with the relevance of the assessment to the needs of decision-makers' (Cash et al., 2003, p. 8086). Some authors prefer to use the term 'relevance' instead of salience (Heink et al., 2015; Sarkki et al., 2014; Tuinstra et al., 2006). In this paper, we use the terminology as introduced by Cash et al. (2003), which includes salience. It may involve responsiveness to policy or management needs and the capacity to influence policies or management practices (Heink et al., 2015).

The triad of legitimacy, credibility, and salience has been applied in studies within various domains of environmental policy and management, including air pollution (Tuinstra et al., 2006), climate change (Shaw, Danese, & Stocker, 2013), nature conservation (Hauck et al., 2013), coastal and marine management (Röckmann, Van Leeuwen, Goldsborough, Kraan, & Piet, 2015; Runhaar et al., 2016), biofuel policy (Schut, Van Paassen, & Leeuwis, 2013), and landscape planning (An & Powe, 2015). These studies generally acknowledge that legitimacy, credibility, and salience need to be combined in order to successfully mobilize knowledge for decision-making, policy-making, or other forms of collective action concerning the natural environment. Moreover, it has been argued that trade-offs between these three attributes may occur, as 'efforts to enhance any one normally incur a cost to the others' (Cash et al., 2003, p. 8086; see also Pietri et al., 2011; Runhaar et al., 2016; Sarkki et al., 2014). Therefore, combining the three attributes can be seen as a challenging 'balancing act' (Kunseler, Tuinstra, Vasileiadou, & Petersen, 2015, p. 2).

Balancing legitimacy, credibility, and salience is often seen as a matter of boundary management between knowledge creation and decision-making. Such boundary management involves knowledge brokering across science-policy boundaries, and the establishment of boundary organizations that serve as intermediaries between science and policy (Cook et al., 2013; Van Enst, Runhaar, & Driessen, 2016). For instance, Cash et al. (2003, p. 8089) argue that

> those systems that made a serious commitment to managing boundaries between expertise and decision making more effectively linked knowledge to action than those that did not. Such systems […] more effectively balanced salience, credibility, and legitimacy in the information they produced.

Although it is widely acknowledged that trade-offs may occur between legitimacy, credibility, and salience, little scholarship has explicitly focused on identifying such trade-offs in practice. A notable exception is Sarkki et al. (2014), who identify four trade-offs in science-policy interfaces:

1. Participating in science-policy interfaces versus doing 'regular' scientific or policy work;
2. Presenting clear and simple messages (salience) versus thoroughly addressing epistemic and social complexities (credibility, legitimacy);
3. Providing rapid responses to policy needs (salience) versus taking time for quality assessments and consensus building (credibility, legitimacy);
4. Supply driven, credibility-oriented knowledge creation versus demand-driven, salience-oriented knowledge creation.

However, synergies between legitimacy, credibility, and salience may occur as well (e.g. Hegger et al., 2012). For instance, exploring a broad range of views in order to achieve legitimacy may also be conducive to quality assessment in the form of 'extended peer review'; thereby creating a synergy between legitimacy and credibility (see also Funtowicz & Ravetz, 1993). However, little empirical research has explicitly focused on identifying such synergies.

Generalized knowledge on trade-offs and synergies between knowledge legitimacy, credibility, and salience is lacking because the ways in which they come about and may be dealt with are often context-specific. Hence, in order to better understand trade-offs and synergies, insight in process- and context-specific factors is needed. For instance, Runhaar et al. (2016) argue that the type of science-policy arrangement and the degree of contestation of the problem are important. Formal, credibility-oriented arrangements may go at the expense of the legitimacy of knowledge creation. In strongly contested situations, more transdisciplinary arrangements and debates on the required kind of knowledge may be more suitable; however, such arrangements may also enhance the emergence of knowledge conflicts (Runhaar et al., 2016). Sarkki et al. (2014, p. 203) argue that the 'social status of scientists and SPIs [science-policy interfaces, …], the stage in the policy cycle, and degree of problem structuration are three particularly important contextual factors which will influence how the trade-offs can be resolved or at least eased'. Furthermore, Röckmann et al. (2015, p. 161) identify various contextual factors that affect the success of stakeholder interaction processes in combining salience, legitimacy, and credibility. These are resource availability, trust between involved actors, the quality of available knowledge, and the willingness of actors, for instance to engage in joint problem framing, learn from each other, and share information.

With this paper, we aim to contribute to insight into contextual factors that may affect the balancing of legitimacy, credibility, and salience in collaborative knowledge creation. For this purpose, we examine both the trade-offs and synergies that emerge, and the broader social and institutional setting in which this knowledge creation is situated.

3. Methods

This paper is empirically informed by interviews and document study on the Ecology-oriented Sand Nourishment (ESN) collaborative arrangement and the research program that is part of this arrangement. In this paper, the term 'arrangement' signifies a more or less stabilized or institutionalized practice or platform in which different groups of interested actors interact or collaborate. In a first round, policy-related and societal

developments concerning 'ecological' or 'natural' approaches to coastal defense in The Netherlands were broadly investigated on the basis of scholarly literature, research reports and 'grey' literature such as policy documents. The second round zoomed in on the ESN arrangement; 15 semi-structured interviews were conducted with key actors, including researchers who coordinated and executed the research and monitoring, representatives of the participating NGOs and civil servants who were involved in the coordination and management of the program. The interview topics included the establishment of the collaborative arrangement, the programing of the research, the interactions between the actors involved, and the main issues that played a role in this case. Furthermore, we asked how interviewees perceived the salience, legitimacy, and credibility of the research program. Our interview guide operationalized these concepts by including questions about whether the program addressed the interviewees' concerns (legitimacy), how the interviewees assessed the quality of the research (credibility), and how the research program was connected to decision-making and management (salience). Most interviews lasted between 45 min and 2 h. The interviews were recorded, transcribed verbatim, and analyzed with software for qualitative data analysis (Nvivo 10). We used an inductive coding strategy on the basis of the issues that were brought up by the respondents (Lofland, Snow, Anderson, & Lofland, 2006). Furthermore, we used credibility, legitimacy, salience, and the trade-offs and synergies between these attributes as analytic codes (Lofland et al., 2006). We operationalized these three attributes in the following way:

- References to the (possibly diverging or conflicting) concerns and viewpoints of actors regarding coastal protection and nature, and how these were dealt with in the program, were categorized under legitimacy.
- References to the quality, validity, reliability, and methodology of the research and the produced knowledge were categorized under credibility.
- References to how the program relates to decision-making, policy, or management were categorized under salience.

The analysis was bolstered through triangulation with written sources that were produced in the context of the collaborative arrangement, such as research plans, legal documents, workshop reports, and research reports.

4. Coastal policy and management background

The Netherlands, with almost one-third of its territory below sea-level, has a long history of protecting its inhabitants and land from flooding (Van Koningsveld, Mulder, Stive, Van der Valk, & Van der Weck, 2008). 75% of its 400 km long coastline is protected by sandy structures and dune areas; the remainder is protected by hard structures such as dams, dikes, and storm surge barriers (De Ruig, 1998; Mulder, Hommes, & Horstman, 2011). Due to an imbalance between sediment supply and sea level rise, the sandy coast has eroded during at least the last centuries, and presumably for up to 1500 years (Bakker, Van Heteren, Vonhögen, Van der Spek, & Van der Valk, 2012). This has caused land loss and threats to, e.g. drinking water supply and ecological, residential, and industrial functions in the coastal zone (Van Koningsveld & Mulder, 2004).

Before 1990, the Dutch coastal defense policy aimed at countering only the most urgent erosion problems through fixating and restoring dunes and creating sand dikes (De Jong, Keijsers, Riksen, Krol, & Slim, 2014; De Ruig, 1998). However, by 1990 it became clear that this policy would not suffice for safeguarding the Dutch coast in the long run (Hillen & Roelse, 1995). Therefore, a new policy was implemented that aims at fully countering coastal erosion, thus maintaining the Dutch coastline at its 1990 position (Rijkswaterstaat, 1990). This policy has been implemented through a management program that includes the monitoring of the coastal sediment volume and sand nourishments (Bakker et al., 2012). This program is executed by Rijkswaterstaat (RWS), the executive organization of the Department of Infrastructure and the Environment.

Sand nourishment entails collecting sand from the deeper parts of the North Sea (outside the 20 m isobath), and depositing it on the shoreface or the beach, where water and wind determine its further transport and accumulation across the coastal zone (De Jong et al., 2014; Hillen & Roelse, 1995). The new policy is called 'dynamic preservation' because it aims to preserve the coast by using and stimulating the natural dynamics of sand and water; it has therefore also been characterized as 'building with nature' (De Jong et al., 2014;

Kabat et al., 2009; Van Koningsveld & Mulder, 2004). Various evaluations have found the policy successful in maintaining the coastline's reference position (Mulder et al., 2011). Moreover, the policy is thought to be sustainable in the long run as it allows the coast to grow along with sea-level rise (Kabat et al., 2009). However, the ecological effects, which may be positive or negative in various parts of the coastal zone, such as the foreshore, the beach, and the dunes, are not well understood. Several environmental NGOs have been involved in discussions about these effects, with diverging concerns that relate to their particular focus on, for instance, marine conservation, bird protection, or dune conservation.

5. Efforts to achieve legitimacy, credibility, and salience in the ESN program

5.1. The establishment of the ESN program

Since 1990, RWS has been executing its program of sand nourishments along the Dutch coast. Initially, it carried out these nourishments as regular infrastructural maintenance. Therefore, it deemed requesting permits for sand nourishments unnecessary:

> RWS was of the opinion that it fell under the regular maintenance of the system. […] We do not need to request a permit for replacing a layer of asphalt on the freeway either. [RWS adviser]

However, by the mid-2000s a group of nature conservation NGOs had started to criticize that the execution of sand nourishment was unregulated and that little was known about the ecological effects. One NGO representative involved at the time stated:

> We had no problem with dynamic preservation as such, but we did have a problem with the way it was executed, its unregulated character, the lack of research underpinning its execution, and also the lack of knowledge on its optimization with regard to nature. [NGO representative 1]

Consequently, four NGOs (Wadden Sea Society, Society for the Protection of Birds, Dune Conservation Foundation and North Sea Foundation) formed a coalition to address these issues. They demanded that RWS should request permits for sand nourishments under the Dutch Nature Conservation Act (NCA), which would impose a formal decision-making and consultation procedure on sand nourishments. Moreover, it would impose a systematic monitoring of the ecological effects of sand nourishments, as the NCA mandates a scientific assessment of such effects.[1] However, RWS initially did not intend to meet the demands of the NGOs. One of the NGOs' representatives for instance recalled:

> We put quite some pressure on RWS to request an NCA-permit for the sand nourishments […]. That was extremely laborious […]. There were people at RWS who absolutely did not feel like doing so and who thought that they as a governmental organization were not obliged to. [NGO representative 2]

RWS's resistance incited the NGOs to take various formal actions, including issuing comments in the consultation procedure concerning the annual sand nourishment program and filing 'enforcement requests' to the province of Fryslân and the Department of Agriculture, Nature, and Food Quality. An enforcement request is a message to a competent authority that points out a possible breach of a regulation, and that requests the enforcement of this regulation. In response, RWS started requesting NCA permits for sand nourishments in 2008, which have been regularly granted. However, the NGOs used the consultation procedures for the first permits to argue that the permit conditions and impact assessments were inadequate, and that integrated research on large-scale and long-term ecological effects was needed.[2]

In response, RWS proposed the 'Collaborative Agreement Sand Nourishments' (2009), in which RWS and the NGOs agreed to collaborate on a research and monitoring program that aimed at 'gaining more knowledge on the influence of the execution of sand nourishments on natural values, and on possibilities of optimizing the sand nourishment program and its execution regarding the conservation and development of natural values'.[3] The NGOs agreed to 'exercise restraint in taking recourse to legal remedies' with respect to sand nourishments.[4]

The ensuing ESN research program was executed in collaboration between RWS, the four NGOs, and the research organization Deltares.[5] Furthermore, the fieldwork was carried out by several specialized private

research agencies (including the Belgian agency eCoast and the Dutch agencies EGG Consult and The Fieldwork Company) who worked in annual contracts under the authority of Deltares. The ESN program was embedded in the larger research program 'KPP Management and Maintenance Coast' (KPP Coast), which is coordinated by RWS and Deltares, and provides RWS with the knowledge required for optimizing the dynamic preservation of the Dutch coast.[6] Through introducing ESN in KPP Coast, an ecological subprogram was added to a research program that previously solely focused on coastal morphology.

After 2009, research activities under the ESN program included:

- A study on the ecological effects of sand nourishment on the dunes along the Dutch coast, in collaboration with the research network for nature management O + BN (Arens et al., 2012).[7]
- A literature study on the likely spatial and temporal effects of sand nourishments on birds (Jonkvorst, Gyimesi, Boudewijn, & Poot, 2013).
- A case study on the effects of sand nourishments on the ecology of the foreshore and beach of the island of Ameland formed the principal part of the ESN program. One of its key research questions was the speed of ecosystem recovery after sand nourishments (Holzhauer et al., 2014). Ameland was chosen for pragmatic reasons; at the time the research program was started up, there were already plans for sand nourishments near Ameland that could serve as a case study.

5.2. Efforts to achieve legitimacy

Through their initiatives, the nature conservation NGOs established ecology on the coastal protection research agenda. RWS and Deltares made efforts to ensure that the content of the ESN research program reflected the NGOs' various concerns, which differed to some extent. For instance, the Wadden Sea Society was interested in the effects of sand nourishments on the ecological and morphological systems of the Dutch Wadden Sea, the Society for the Protection of Birds in the effects on the coastal food web, and the Dune Conservation Foundation in the possible contribution of sand nourishments to the restoration of dune ecosystems.[8]

The creation of a legitimate research program was a process in which the concerns of the NGOs and the focus of the research practice were aligned in several ways. First, tentative research questions were formulated on the basis of the concerns put forward by the NGOs in their comments during the consultation procedure concerning the permit for the sand nourishment program:

> As a basic source we had the comments that had been submitted. They included an appendix with […] a big pile of questions and concerns and doubts about sand nourishment […]. Together with IMARES and Deltares […] we analyzed how we could turn those doubts and concerns into research questions.[9] [RWS program manager]

Subsequently, the further specification of the focus, the questions and the set-up of the research were discussed in three workshops with representatives of RWS, the NGOs, and research organizations in the summer of 2009. The results of these workshops served as input for the 5-year research plan that was finalized in late 2009, which served as the basis for subsequent annual research plans.[10] The 5-year research plan contained 31 research questions on the ecological effects of sand nourishment that are detailed into five themes that roughly cover the concerns of the NGOs (Holzhauer, Van der Valk, Van Dalfsen, Baptist, & Janssen, 2009):

1. Large-scale ecological and morphological systems, specifically those of the Wadden Sea.
2. Three types of habitats:
    a. Offshore (i.e. the deeper parts of the North Sea where sand is collected),
    b. The foreshore and the breaker shore,
    c. The beach and the dunes.
3. Food web relations.

During the execution of the research program, the program leaders aimed to ensure the legitimacy of the program by means of regular deliberation between RWS, the NGOs, and the researchers. Notably, interim results

and possible adjustments to the research plans were discussed by the involved parties in annual workshops. However, representatives of the NGOs argued that it was difficult for them to stay actively involved in the deliberations, because they had to divide their limited time and manpower among a range of issues and developments. Once the issue of the ecological impact of sand nourishments was placed on the agenda and solidified in the collaborative agreement, other issues demanded more attention. One of the NGOs' representatives for instance argued about the shifting priorities:

> Such is […] the fate of these kinds of covenants […]. In the build-up they take priority and everyone is strongly involved. Once they have been settled […] they become less primary on the agenda. There is a risk to that. […] It then becomes quite difficult to keep a finger on the pulse. [NGO representative 2]

5.3. Efforts to achieve credibility

Throughout the programing and the execution of the ESN research program, the involved researchers from Deltares and the other research organizations made various efforts to create a credible research program. Deltares, which had the prime responsibility for the program's technical and scientific quality (Holzhauer et al., 2009), transformed the tentative questions into a set of scientifically researchable questions that fit under the five main themes of the program. After some filtering and adjusting, a further focus in the research program emerged. A program manager explained:

> We tried to fit the directly answerable questions into the components that we had, and to adjust the questions that required very long or expensive research or that we simply could not answer [by asking]: what is the question that we should ask instead? [Deltares program manager]

Furthermore, quality control served to enhance the credibility of the research program, including a peer-review process to assess the scientific quality of the 5-year research plan The review stimulated methodological adjustments and a stronger focus on linking fundamental ecological research to the practical applicability of the results (Holzhauer, 2010).

Moreover, the credibility of the program was enhanced by involving several specialized ecological research and monitoring agencies in the execution of the monitoring; these agencies produced detailed methodological designs and fieldwork reports on both the case study on Ameland and the research on the ecological effects on dunes (e.g. Everts & De Vries, 2010; Vanagt et al., 2011):

> We handle a part of the questions ourselves but we work together with many other parties who do parts of the research, with an eye to doing research that has a broader foundation than something that was simply and solely contrived between these four walls. […] Often there are portions of the research for which we don't have the best and highest credentials; in that case other parties are better suited for the job. [Deltares program manager]

Some of the involved researchers questioned whether the statistical power, the set-up and the execution of the monitoring were scientifically adequate to measure the ecological effects of sand nourishments. For instance, monitoring was hampered because the contractor of the sand nourishments had a flexible planning for executing the work. Therefore, the researchers were not able to work according to a predetermined sampling plan (Holzhauer et al., 2014, p. viii). Furthermore, various interviewees pointed out that, because of its spatial and temporal limitations, the case study was not representative with respect to the effects of sand nourishment on a larger scale, on a longer term, and in other parts of the Dutch coast. Consequently, the involved researchers have called for a nuanced interpretation of the results of the program. In sum, the credibility of the research program received much attention, for instance in the formulation of research questions, the involvement of experts, and the methodological design; at the same time, there were trade-offs with practical considerations and circumstances. These will be further elaborated in section 6.

5.4. Efforts to achieve salience

Since its purpose was to provide knowledge for the optimization of sand nourishments with respect to 'natural values',[11] the ESN research program strongly aimed at producing salient knowledge for the practice of 'dynamic

preservation'. As a first step in achieving salience, the notion of what constitutes salient knowledge for dynamic preservation was redefined. Prior to the collaborative agreement, sand nourishment was not regulated under the Nature Conservation Act (NCA). Thus, ecological knowledge was not officially considered to be salient for dynamic preservation and research and monitoring in the KPP Coast program focused on geomorphological aspects of the coast. Following the NGO's intervention, ecological effects were legally mandatory to be taken into account in the decision-making on the permissibility of sand nourishments, making ecological research relevant for the practice of dynamic preservation. As a second step, the parties to the agreement shaped the salience of the ESN program by programing the research in such a way that specific sub-projects served as sources of knowledge for the decision-making on sand nourishments under the NCA permit regime. Within the program, several short-term research projects were executed, e.g. on the behavior of seals and sanderlings (*Calidris Alba*) in relation to sand nourishments, with the explicit aim of providing knowledge for permit requests.[12]

Furthermore, the salience of the ESN program was shaped by the program's institutional design. Embedding ESN in the KPP Coast program made it part of an already existing management-oriented research infrastructure. Following the institutional logic of the KPP Coast program, ESN was coordinated, like other subprograms, in close collaboration between the program managers of RWS and Deltares. Consequently, RWS was continuously involved in assessing and safeguarding the salience of the research. For instance, an RWS program manager stated:

> One of the research questions concerns the effects of sand quality. […] We concluded that addressing that question might produce results, but we would not be able to apply them in the execution [of sand nourishments], so we let that rest for the time being. […] It is aimed at improving sand nourishments, not just at knowing more. [RWS program manager].

Finally, the program aimed to provide salient knowledge through contributing to design principles or a guideline for ecologically sound sand nourishment. Such principles, which may for instance concern the intensity, phasing, and sediment composition of sand nourishments,[13] have not yet been formulated. As one of the NGOs' representatives stated:

> The aim of the research is to produce a guideline for ecological nourishment. The results are now known. […] As yet we haven't thought through: how are we going to do things differently than in the past? [NGO representative 3]

This may be explained by the results, which have not yet given cause to radical adjustments to the sand nourishment practice, as one of the program managers suggested:

> [The research] does not indicate that we have to do things radically differently. Either we don't know enough yet about the relations between sand nourishments and dynamics, or the recovery time [of the ecosystem] is not much longer than the repetition time of the beach nourishments. [RWS program manager]

6. Legitimacy, credibility, and salience: trade-offs and synergies

6.1. Legitimacy – salience: synergy between addressing concerns and informing decision-making

In the ESN research program, a synergy between legitimacy and salience emerged in several ways. Firstly, the ecological concerns put forward by the NGOs were embedded in knowledge creation and decision-making on the 'dynamic preservation' of the coast. The decision that sand nourishment falls under the NCA permit regime implies that ecological issues have to be addressed in permission proceedings and monitoring. Moreover, ecological research appears to have gained a structural position in the KPP Coast program, as a program manager reflected:

> For 25 years we have been working on how we manage our coast, what we see there and what we can learn from it. The ecological part that has entered now is still in its infancy. It is starting to stand on solid ground, […] we will continue to work on it in a structured way [Deltares program manager]

Thus, both in the context of the NCA permit regime and the KPP Coast program, addressing the ecological concerns of the NGOs gave a positive impulse to the underpinning of the decision-making on the execution of sand nourishments.

Secondly, a collaboration developed in which the boundary between 'stakeholders' and 'decision-makers' became more permeable. For instance, the NGOs have exerted a strong influence on the way decisions on sand nourishments are made, by inciting RWS to apply for permits under the NCA. Furthermore, RWS and the NGOs have been working toward the shared goal of optimizing sand nourishments with respect to ecology, and the NGOs have been consulted in early stages of decision-making on the sand nourishment program. In this sense, addressing ecological concerns and making decisions on the execution of sand nourishments have become more tightly coupled.

6.2. Salience – credibility: trade-off between practical relevance and scientific quality

The ESN research program provided room for discussing and safeguarding both the scientific adequacy and the relevance of its results. This is exemplified by the expert review of the 5-year research plan, which resulted in a stronger focus on the practical relevance of the program's results for coastal management (Holzhauer, 2010). In this sense, the program combined credibility and salience. However, trade-offs between the two also occurred, notably due to the institutional design and embedment of the program.

The ESN program aimed at providing salient knowledge for the practice of 'dynamic preservation'. This salience was reinforced by making the program a part of the already existing management-oriented knowledge infrastructure of the KPP Coast program. However, following the institutional mechanisms and rules of this program presented a drawback with respect to credibility. One of these institutional mechanisms was a contracting model, under which research projects were put out to tender on a yearly basis. Thus, multi-year research projects, including the ESN program, were executed by contractors that could fluctuate from year to year. Consequently, it was difficult to create a stable community of researchers and to safeguard the continuity of the research process. In this sense, there was a trade-off in the KPP Coast program between achieving a scientifically ideal research practice and embedding the program in a management-oriented knowledge infrastructure. One of the researchers concluded:

> The way [the research] was contracted out in many different ways, resulting in a lack of a logical continuity of its […] execution, is definitely a point for improvement [Researcher 1]

Another researcher complained about the contracting model:

> It takes away the continuity of your project and moreover it completely removes the zest, the cooperation and the mutual goodwill of the researchers. [Researcher 2]

Moreover, it was argued that the management-oriented institutional design of the program was in tension with the state of ecological knowledge, i.e. the many scientific knowledge gaps. Some of the interviewed researchers argued that fundamental and long-term scientific research, including basic research on the ecology of the foreshore and on the long-term and large-scale effects of sand nourishments, was first needed before more applied research could be done. As one of them stated:

> [The research] is actually so fundamental because it purely concerns knowledge creation about an almost unknown area; therefore, I wonder whether it should be done in a program like this, or be led in a much broader setting, or placed with NWO.[14] [Researcher 3]

6.3. Legitimacy – credibility: trade-off between issue diversity and depth of inquiry

The translation of the NGOs' concerns into researchable questions resulted in a focus of the program that to some extent met the requirements of both legitimacy and credibility. At the same time, there were clear trade-offs between these two knowledge attributes. On the one hand, spreading the resources of the program among the various issues of ecological concern raised by the NGOs imposed limited the depth of inquiry. In other words, the democratization of the research programing in order to achieve legitimacy limited the credibility of the research, given the limited resources. One of the interviewed researchers argued:

> One expects that in such a dynamic area […] the differences are subtle. This means that measurements should have high [statistical] power, which they hadn't. That is because […] the scientific arguments are not the most important. There are people at the table with different backgrounds and interests. [Researcher 2]

On the other hand, the translation work towards researchable questions also resulted in a research focus that only partly reflected the concerns of the NGOs. Thus, the parties involved were also confronted with a trade-off between researchability and the accommodation of their various concerns. Notably concerns about the impacts of sand nourishments on a large-scale systems level were left unaddressed due to perceived limits to their researchability (see also section 6.2). For instance, an NGO representative argued:

> The most difficult issue to address […] has been the impact of sand nourishments on the Wadden Sea. This had a technical motivation; for a very long time it was maintained that this impact was unmeasurable […] either because of background noise, or because it concerns such a small amount of sand. I have never chosen to fully believe that. [NGO representative 2]

Finally, the ESN program rested on the implicit assumption that a synergy between creating credible and legitimate knowledge could be achieved by facilitating regular in-depth discussions between researchers and representatives of the NGOs about the programing and the results of the research. However, this was difficult in practice due to different levels of scientific expertise and the limited time and resources of the NGOs (see also section 5.2). Also in this sense, a tension between legitimacy and credibility occurred in the ESN program. One of the interviewed researchers for instance stated:

> What I always miss a bit is a clear input from the NGOs with respect to content. […] The flaw is that they lack substantive research knowledge. But meanwhile they were the ones to whom account was given. Now and then I thought that was a bit complicated. [Researcher 3]

7. Discussion and conclusions

Successful environmental management needs effective linkages between knowledge creation and environmental action, which in turn requires knowledge creation efforts that combine legitimacy, credibility, and salience. This paper has aimed to create insights about trade-offs and synergies between these three knowledge attributes by examining the efforts to achieve legitimacy, credibility, and salience in the context of a collaborative research program on ecology-oriented coastal defense in the Netherlands.

Our findings suggest that the legitimacy and salience of knowledge creation for environmental management, particularly in a governance context with strong interactions between societal and governmental actors, is likely to overlap and be complementary. For instance, addressing the concerns of NGOs in a collaborative research process may at the same time provide salient knowledge for environmental decision-making or management. In this sense, a synergy between legitimacy and salience can emerge. Our findings also show that in such multi-actor, collaborative settings, several trade-offs are likely to occur. Our analysis has identified two main trade-offs that both involve credibility. Firstly, our findings indicate a trade-off between creating practically relevant knowledge for environmental management (salience) and creating in-depth, fundamental knowledge on the environment (credibility). This trade-off corresponds to both the clarity-complexity and push–pull trade-offs described by Sarkki et al. (2014). Furthermore, we have identified a trade-off between legitimacy and credibility. Addressing a diversity of concerns may impose limits to the depth of inquiry; simultaneously, efforts to achieve scientific researchability may come at the cost of addressing some of the stakeholders' concerns. This is a trade-off between issue diversity on the one hand and the depth and quality of scientific inquiry on the other, given limited resources available for knowledge creation.

Previous research by Cash et al. (2003) and others suggests that trade-offs between legitimacy, credibility, and salience are often inevitable. However, how and which trade-offs become manifest is contingent upon context-specific factors. Consequently, a highly relevant question is which factors and conditions may influence the emergence of such trade-offs, and which may help to address them.

Our findings indicate that the type of problem is an important factor in the emergence of trade-offs between legitimacy, credibility, and salience of knowledge. For instance, a combination of uncertainty, knowledge gaps and diverging concerns and interests (which is typical for 'wicked' or 'unstructured' problems) may cause

several trade-offs (Runhaar et al., 2016; Sarkki et al., 2014). In the case examined here, the combination of fundamental knowledge gaps and a diversity of concerns and interests among NGOs and policy-makers gave rise to trade-offs between legitimacy and credibility, and between salience and credibility. In collaborative knowledge creation processes with a higher degree of conflict between societal and governmental organizations than in our case, trade-offs between legitimacy and salience are also likely to emerge.

Often such trade-offs cannot be resolved; dealing with them is rather a balancing act (cf. Kunseler et al., 2015). Our results suggest that balancing legitimacy, credibility and salience of knowledge may be enabled by means of collaborative arrangements that provide room for intensive and iterative interactions between stakeholders, policy-makers, and researchers. Such interactions may involve knowledge exchange, joint problem formulation and research programing, and (re)framing of the problem and possible solutions. Moreover, they may involve redefining what knowledge is considered legitimate, salient and credible. In the case examined here, the kind of knowledge that was deemed salient shifted due to changes in the assessment and decision-making process that were instigated by the NGOs. Similarly, legitimacy and credibility may be redefined or reframed. For instance, efforts to achieve legitimacy may involve a reassessment of the range of relevant stakeholders; efforts to achieve credibility may involve rethinking the standards that are used to evaluate the quality of knowledge. Thus, our results suggest that legitimacy, credibility, and salience are not standards that are set in stone, but rather fluid, dynamic, and negotiable attributes.

Several factors may play a role in establishing and maintaining the stakeholder interactions that enable balancing the legitimacy, credibility and salience of knowledge. These include the pressure or necessity to collaborate, willingness among involved parties, and trust (Röckmann et al., 2015; Van der Molen, Puente-Rodríguez, Swart, & Van der Windt, 2015). Our findings suggest that the capacity of involved actors to engage in interactive processes, in terms of time, resources and expertise, is also an important factor. Moreover, our findings show that broader institutional and regulatory contexts may play an important role in establishing such processes. Existing research or monitoring programs, legal frameworks, and networks may provide several beneficial factors and conditions, such as access to resources and expertise, existing networks and collaborations, and already-established linkages with decision-making and management processes. Therefore, an important lesson from our research is that linking environmental knowledge and environmental action in situations of uncertainty and ambiguity requires both a careful design of arrangements for stakeholder interaction, and well-established linkages to the broader context of existing institutions, networks and regulations.

This paper has investigated strategies to achieve legitimacy, credibility, and salience in collaborative environmental research, and the trade-offs and synergies between these three attributes. It has investigated these processes in a rather inductive manner and from an internal perspective, focusing on the experiences of actors that participated in the program. A shortcoming of this approach is that it does not enable more objective assessments or measurements of the legitimacy, credibility, and salience that were achieved. However, it is clear that more universal assessment criteria for the three attributes can be useful, for instance for evaluating research programs, or for research that aggregates or compares insights from various cases. An important question for future research is how such criteria can be combined with the in-depth investigation of specific cases and contexts, and of the experiential knowledge of involved actors.

Notes

1. This assessment is called an 'appropriate assessment'.
2. E.g., Province of Fryslân (2008) Permit Nature Conservation Act 1998, for sand nourishment near Texel, North Sea Coastal Zone, 00781007; Wadden Sea Society (2008) Objection Against the Permit Nature Conservation Act 1998 Sand Nourishment, AWo/AW/08099.
3. Collaborative Agreement Sand Nourishments Nature Conservation Organizations and Rijkswaterstaat (2009), p. 2.
4. Collaborative Agreement Sand Nourishments Nature Conservation Organizations and Rijkswaterstaat (2009), p. 3.
5. Deltares is a merger of various water and civil engineering research organizations including several former research departments of RWS; it serves as one of the principal 'knowledge suppliers' of RWS.
6. KPP stands for 'Knowledge for Primary Processes'. The wiki site of this program can be found at https://publicwiki.deltares.nl/pages/viewpage.action?pageId=72844168 [last visited 01-25-2016].

7. O+BN is a Dutch acronym for Development and Management Nature Quality. It is a research network that aims to create and disseminate application-oriented knowledge for environmental management.
8. The Wadden Sea is a protected intertidal area that stretches from the northern coast of the Netherlands to the western coast of Denmark.
9. IMARES, the Institute for Marine Resources & Ecosystem Studies, was involved in the initial stages of the research program.
10. Workshop Report Effects of Sand Nourishments on Dunes (Knowledge Lacunae and Research Questions), 29 June 2009, Harlingen.
11. Collaborative Agreement Sand Nourishments Nature Conservation Organizations and Rijkswaterstaat (2009), p. 2.
12. Report of results workshop 2010 (2011).
13. Meeting Report, Designing an Ecological Sand Nourishment, 25 August 2009.
14. NWO is the Netherlands Organisation for Scientific Research; it funds scientific research at public research institutions in the Netherlands.

Acknowledgements

We thank the respondents for sharing their knowledge with us, and three anonymous reviewers for their valuable comments.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Netherlands Organization for Scientific Research (NWO) and the Wadden Academy under grant no. 839.10.151.

Notes on contributors

Dr. Franke van der Molen was trained in science and technology studies, and conducted doctoral research on collaborative environmental research and governance in the Dutch Wadden Sea area. He currently works as a postdoctoral researcher, focusing on the implementation of responsible research and innovation (RRI) in research funding and performing organizations.

Dr. Jac. A. A. Swart is an associate professor at the Science and Society Group (SSG) of the Energy and Sustainability Research Institute Groningen (ESRIG) at the University of Groningen. He was trained as a biologist, and subsequently focused his research on science and technology studies with respect to the natural and life sciences. His research interests include ethics of the life sciences, and the social dynamics of innovation processes. He published on ethical and social aspects of nature conservation and restoration, animal experimentation, ethics of wild animals management, and biotechnology.

Dr. Henny J. van der Windt is an associate professor at the Science and Society Group (SSG) of the Energy and Sustainability Research Institute Groningen (ESRIG) at the University of Groningen. His research topics include the role of scientific expertise in nature conservation and energy transition, co-production of knowledge for sustainability, co-management in coastal areas, co-creation in sustainable agriculture, and environmental history.

References

An, K., & Powe, N. A. (2015). Enhancing 'boundary work' through the use of virtual reality: Exploring the potential within landscape and visual impact assessment. *Journal of Environmental Policy & Planning*, *17*(5), 673–690.

Arens, S. M., Everts, F. H., Kooijman, A. M., Leek, S. T., Nijssen, M., & De Vries, N. P. J. (2012). *Ecologische effecten van zandsuppletie op de duinen langs de Nederlandse kust* (No. 2012/OBN166-DK). The Hague: Department of EL&I.

Bakker, M. A., Van Heteren, S., Vonhögen, L. M., Van der Spek, A. J. F., & Van der Valk, B. (2012). Recent coastal dune development: Effects of sand nourishments. *Journal of Coastal Research*, *282*(3), 587–601.

Bauler, T. (2012). An analytical framework to discuss the usability of (environmental) indicators for policy. *Ecological Indicators*, *17*, 38–45.

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., … Mitchell, R. B. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences*, *100*(14), 8086–8091.

Cook, C. N., Mascia, M. B., Schwartz, M. W., Possingham, H. P., & Fuller, R. A. (2013). Achieving conservation science that bridges the knowledge–action boundary. *Conservation Biology*, *27*(4), 669–678.

De Jong, B., Keijsers, J. G., Riksen, M. J., Krol, J., & Slim, P. A. (2014). Soft engineering vs. a dynamic approach in coastal dune management: A case study on the North Sea barrier island of Ameland, the Netherlands. *Journal of Coastal Research*, *296*(4), 670–684.

De Ruig, J. H. (1998). Coastline management in The Netherlands: Human use versus natural dynamics. *Journal of Coastal Conservation*, *4*(2), 127–134.

Everts, F. H., & De Vries, N. P. J. (2010). *Plan van Aanpak Ecologische effecten van zandsuppletie op de duinen langs Nederlandse kust* (No. 890EGG). Groningen: EGGconsult Everts & De Vries.

Funtowicz, S. O., & Ravetz, J. R. (1993). Science for the post-normal age. *Futures*, *25*(7), 739–755.

Hauck, J., Görg, C., Varjopuro, R., Ratamäki, O., Maes, J., Wittmer, H., & Jax, K. (2013). "Maps have an air of authority": potential benefits and challenges of ecosystem service maps at different levels of decision making. *Ecosystem Services*, *4*, 25–32.

Hegger, D., Lamers, M., Van Zeijl-Rozema, A., & Dieperink, C. (2012). Conceptualising joint knowledge production in regional climate change adaptation projects: Success conditions and levers for action. *Environmental Science & Policy*, *18*(0), 52–65.

Heink, U., Marquard, E., Heubach, K., Jax, K., Kugel, C., Neßhöver, C., … Timaeus, J. (2015). Conceptualizing credibility, relevance and legitimacy for evaluating the effectiveness of science–policy interfaces: Challenges and opportunities. *Science and Public Policy*, *42*(5), 676–689.

Hillen, R., & Roelse, P. (1995). Dynamic preservation of the coastline in the Netherlands. *Journal of Coastal Conservation*, *1*(1), 17–28.

Holden, M. (2013). Sustainability indicator systems within urban governance: Usability analysis of sustainability indicator systems as boundary objects. *Ecological Indicators*, *32*, 89–96.

Holzhauer, H. (2010). *Kustlijnzorg-ecologie: Resultaten onderzoeksprogramma 2009*. Utrecht: Deltares.

Holzhauer, H., Vanagt, T., Lock, K., Van Oeveren, M. C., De Backer, A., Hostens, K., … Reinders, J. (2014). *Ecologische effecten suppletie Ameland 2009–2012: Interim rapportage ihkv KPP B&O Kust Ecologie*. Utrecht: Deltares.

Holzhauer, H., Van der Valk, B., Van Dalfsen, J., Baptist, M., & Janssen, G. (2009). *Ecologisch gericht suppleren, nu en in de toekomst: Het ontwerp meerjarenplan voor monitoring en (toepassingsgericht) onderzoek*. Utrecht: Deltares.

Jonkvorst, R. J., Gyimesi, A., Boudewijn, T. J., & Poot, M. J. M. (2013). Kustvogels & zandsuppleties: Overzicht van de ecologie en het voorkomen van Nederlandse kustvogels in relatie tot de effecten van zandsuppleties (No. 12-165). Culemborg: Bureau Waardenburg.

Kabat, P., Fresco, L. O., Stive, M. J., Veerman, C. P., Van Alphen, J. S., Parmet, B. W., … Katsman, C. A. (2009). Dutch coasts in transition. *Nature Geoscience*, *2*(7), 450–452.

Koetz, T., Farrell, K. N., & Bridgewater, P. (2012). Building better science-policy interfaces for international environmental governance: Assessing potential within the intergovernmental platform for biodiversity and ecosystem services. *International Environmental Agreements: Politics, Law and Economics*, *12*(1), 1–21.

Kunseler, E., Tuinstra, W., Vasileiadou, E., & Petersen, A. C. (2015). The reflective futures practitioner: Balancing salience, credibility and legitimacy in generating foresight knowledge with stakeholders. *Futures*, *66*, 1–12.

Lofland, J., Snow, D., Anderson, L., & Lofland, L. H. (2006). *Analyzing social settings. A guide to qualitative observation and analysis*. Belmont, CA: Wadsworth / Thomson Learning.

Mulder, J. P., Hommes, S., & Horstman, E. M. (2011). Implementation of coastal erosion management in the Netherlands. *Ocean & Coastal Management*, *54*(12), 888–897.

Pietri, D., McAfee, S., Mace, A., Knight, E., Rogers, L., & Chornesky, E. (2011). Using science to inform controversial issues: A case study from the California Ocean Science Trust. *Coastal Management*, *39*(3), 296–316.

Rijkswaterstaat. (1990). *Kustverdediging na 1990: Beleidskeuze voor de kustlijnzorg*. The Hague: SDU.

Röckmann, C., Van Leeuwen, J., Goldsborough, D., Kraan, M., & Piet, G. (2015). The interaction triangle as a tool for understanding stakeholder interactions in marine ecosystem based management. *Marine Policy*, *52*, 155–162.

Runhaar, H. A., Van der Windt, H. J., & Van Tatenhove, J. P. (2016). Productive science–policy interactions for sustainable coastal management: Conclusions from the Wadden Sea area. *Environmental Science & Policy*, *55*(Part 3), 467–471.

Sarkki, S., Niemelä, J., Tinch, R., Van den Hove, S., Watt, A., & Young, J. (2014). Balancing credibility, relevance and legitimacy: A critical assessment of trade-offs in science–policy interfaces. *Science and Public Policy*, *41*(2), 194–206.

Schut, M., Van Paassen, A., & Leeuwis, C. (2013). Beyond the research–policy interface. Boundary arrangements at research–stakeholder interfaces in the policy debate on biofuel sustainability in Mozambique. *Environmental Science & Policy*, *27*, 91–102.

Shaw, J., Danese, C., & Stocker, L. (2013). Spanning the boundary between climate science and coastal communities: Opportunities and challenges. *Ocean & Coastal Management*, *86*, 80–87.

Tuinstra, W., Hordijk, L., & Kroeze, C. (2006). Moving boundaries in transboundary air pollution co-production of science and policy under the convention on long range transboundary air pollution. *Global Environmental Change*, *16*(4), 349–363.

Van der Molen, F., Puente-Rodríguez, D., Swart, J. A. A., & Van der Windt, H. J. (2015). The coproduction of knowledge and policy in coastal governance: Integrating mussel fisheries and nature restoration. *Ocean & Coastal Management*, *106*, 49–60.

Van Enst, W. I., Runhaar, H. A., & Driessen, P. P. (2016). Boundary organisations and their strategies: Three cases in the Wadden Sea. *Environmental Science & Policy*, *55*, 416–423.

Van Koningsveld, M., Mulder, J. P., Stive, M. J., Van der Valk, L., & Van der Weck, A. (2008). Living with sea-level rise and climate change: A case study of the Netherlands. *Journal of Coastal Research*, *242*(2), 367–379.

Van Koningsveld, M., & Mulder, J. P. M. (2004). Sustainable coastal policy developments in the Netherlands. A systematic approach revealed. *Journal of Coastal Research*, *202*(2), 375–385.

Vanagt, T., Van de Moortel, L., Heusinkveld, J., Vanden Eede, S., Van Steenbrugge, L., Van Hoey, G., & Vincx, M. (2011). *Veldcampagne ecologie Ameland* 2010 (No. 2010014-4). Ostend: eCoast.

White, D. D., Wutich, A., Larson, K. L., Gober, P., Lant, T., & Senneville, C. (2010). Credibility, salience, and legitimacy of boundary objects: Water managers' assessment of a simulation model in an immersive decision theater. *Science and Public Policy*, *37*(3), 219–232.